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November 23, 2016

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Marlene H. Dortch, Secretary
Federal Communications Commission
Office of the Secretary
445 12th Street, SW, Room TW-A325
Washington, DC 20554

Re: Report on Experimental Testing of ATSC 3.0
Experimental Radio License WH2XYY
Ex Parte Notification in GN Docket No. 16-142

Dear Ms. Dortch:

On behalf of LG Electronics, Inc., Zenith Electronics LLC, and GatesAir, Inc., and pursuant to a request from Martin Doczkat, Chief, Technical Analysis Branch, Office of Engineering and Technology, we hereby submit the attached informal report on testing of the Next Generation ATSC 3.0 Digital Television transmission system conducted in the Cleveland, Ohio area. As these test results are pertinent to the pending Joint Petition for Rulemaking to allow television broadcasters to use ATSC 3.0 on a voluntary basis, we are submitting this report in the above-captioned docket.

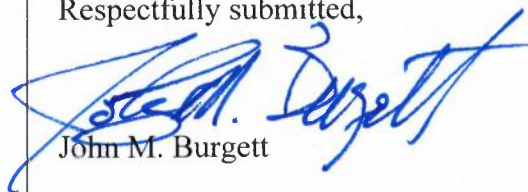
The experimental facilities authorized by Experimental Radio License WH2XYY (File Number 0555-EX-PL-2015) were utilized in June 2016 to conduct a comparison of over-the-air reception performance between ATSC 1.0 and ATSC 3.0. The testing concluded that ATSC 3.0 provides (i) significantly improved mobile reception capability as compared to the ATSC 1.0 A/153 Mobile DTV Standard and (ii) equal or better coverage as compared to the ATSC 1.0 A/53 DTV Standard.

Experimental Radio License WH2XYY was recently assigned to the National Association of Broadcasters, and it is anticipated that the WH2XYY facilities will be used for further industry field testing of ATSC 3.0.

Marlene H. Dortch
November 23, 2016
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Should there be any questions concerning this matter, please contact the undersigned.

Respectfully submitted,



John M. Burgett

cc: Martin Doczkat (by e-mail)

OTA Reception Comparison of ATSC 3.0 to ATSC 1.0

Cleveland, Ohio

June 2016

Per Request of FCC's OET



Goals

- Verify that Reception Performance is equal or better than equivalent thresholds of ATSC 1.0
 - Coverage Comparison
 - All testing was related to the Physical Layer, only
 - Error rates were recorded (no video or audio transmitted)
- Simultaneously test three different robustness levels of ATSC 3.0
 - Robustness equal to ATSC 1.0 (A/53): 14 dB SNR
 - Robustness equal to most used Mobile mode of ATSC 1.0 (A/153): 3.3 dB SNR
 - Better robustness than (A/153): - 1.3 dB SNR
- Comparison to our previous OTA tests with an earlier version of the physical layer

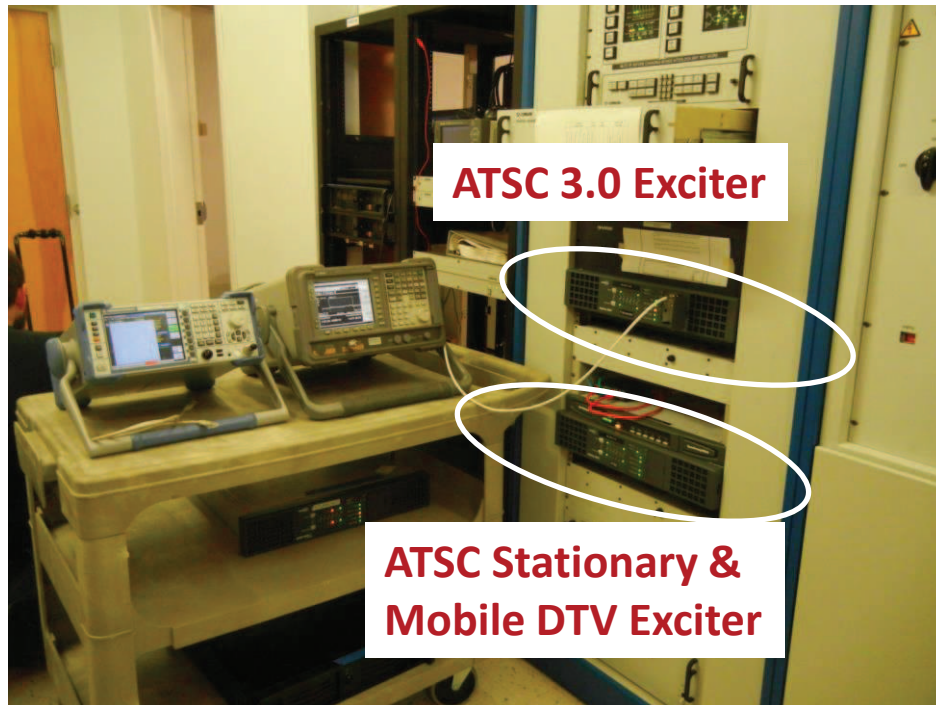
Experimental Station in Cleveland

Owned by Tribune Broadcast

Facilities of WJW, Fox 8

- Experimental License for Channel 31, 572-578 MHz
- 3-Tube, IOT Transmitter
- ERP: 427KW
- Polarization: Horizontal: Omnidirectional
 Vertical: Cardioid pattern North
- Modulation: ATSC 3.0; Candidate Standard, version 45
 - Essentially equal to the current ATSC 3.0 Physical Layer Approved Standards (A/321 & A/322)
 - Three different levels of robustness simultaneously transmitted
- ATSC 1.0 (8-VSB) Modulation for Reference
 - A/53 for stationary reception; A/153 for mobile reception
- Field Testing done in June, 2016

Transmission Facilities



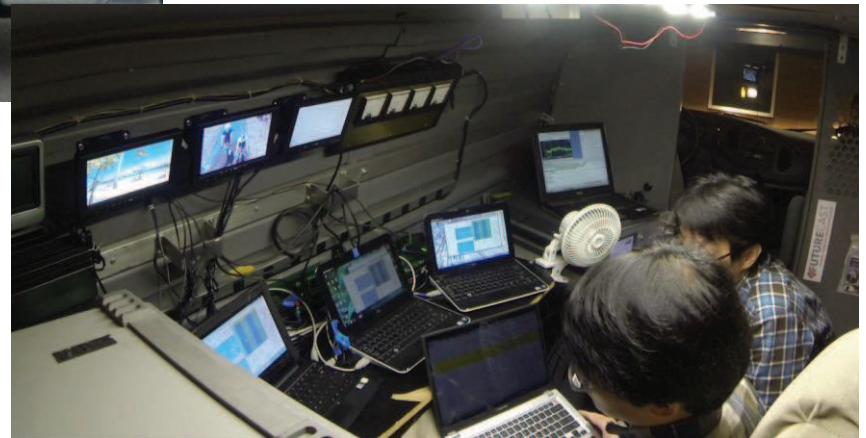
Field Test Considerations

- Zenith Electronics has had many years of Field Testing experience
 - As the primary inventor/developer of the Physical Layer of ATSC 1.0 (DTV, 8-VSB), Zenith did multiple tests in multiple cities before and after the codification of this technology by the FCC in 1996
 - Field Testing of Mobile Digital TV (MDTV = ATSC A/153) was done in multiple cities during the 2008-2015 time frame
 - Early testing of major components of A/322
 - Madison, WI (2014)
 - Cleveland, OH (2015)
- Test Procedures for June 2016 Cleveland testing consistent with teachings of:
 - ATSC Recommended Practice: A/75 – *Developing DTV Field Test Plans; 2001*
 - ATSC 3.0 Recommended Practice: A/326 – *Field Test Plan* [To be Published]
- Each test run was done in both directions
 - One direction, with ATSC 3.0 emission (3 simultaneous modes)
 - Return direction, with ATSC 1.0 (A/53 + A/153) emission
- Many routes chosen for challenging reception conditions
 - Routes NOT chosen to obtain statistical coverage for this station
- ATSC 3.0 Receivers Used
 - LG-built Field Programmable Gate Array (FPGA) – to assure flexibility of receiving technology
 - Programmed for A/322 and A/321 Standards

Mobile Test Van



6" monopole antenna, mounted
at 45 degrees



Mobile Reception in Cleveland

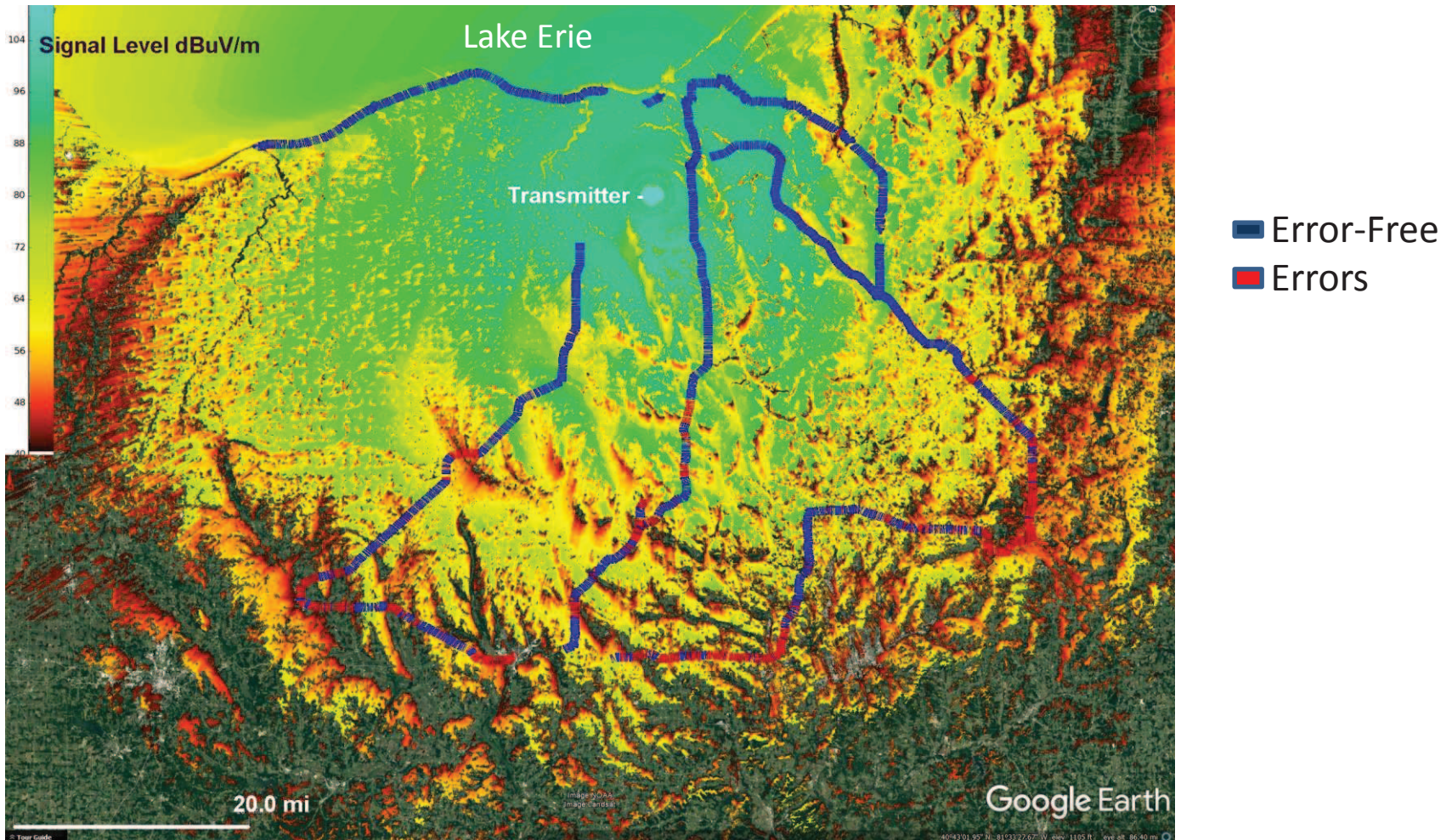
- The emphasis of this testing was: *Mobile Reception*
- Stationary reception of both A/53 and 3.0 was incidental and results are mostly anecdotal
 - Earlier testing with major components of A/322 verified the anticipated much superior *deep indoor* reception with 3.0 using the more rugged modes of 3.0 (AWGN thresholds of < 10 dB)
 - See Appendix B for information about the above earlier tests in Madison, WI and Cleveland, OH

Data Taken

- 35,000 data points for each mobile mode
 - Robustness equal to Mobile mode of ATSC 1.0 (A/153): 3.3 dB SNR
 - Better robustness than (A/153): - 1.3 dB SNR
- 14,700* data points of high-capacity mode (14 dB SNR) during mobile reception
- 14,750 data points of MDTV (A/153) for comparison
- Only a small number of fixed/stationary observations

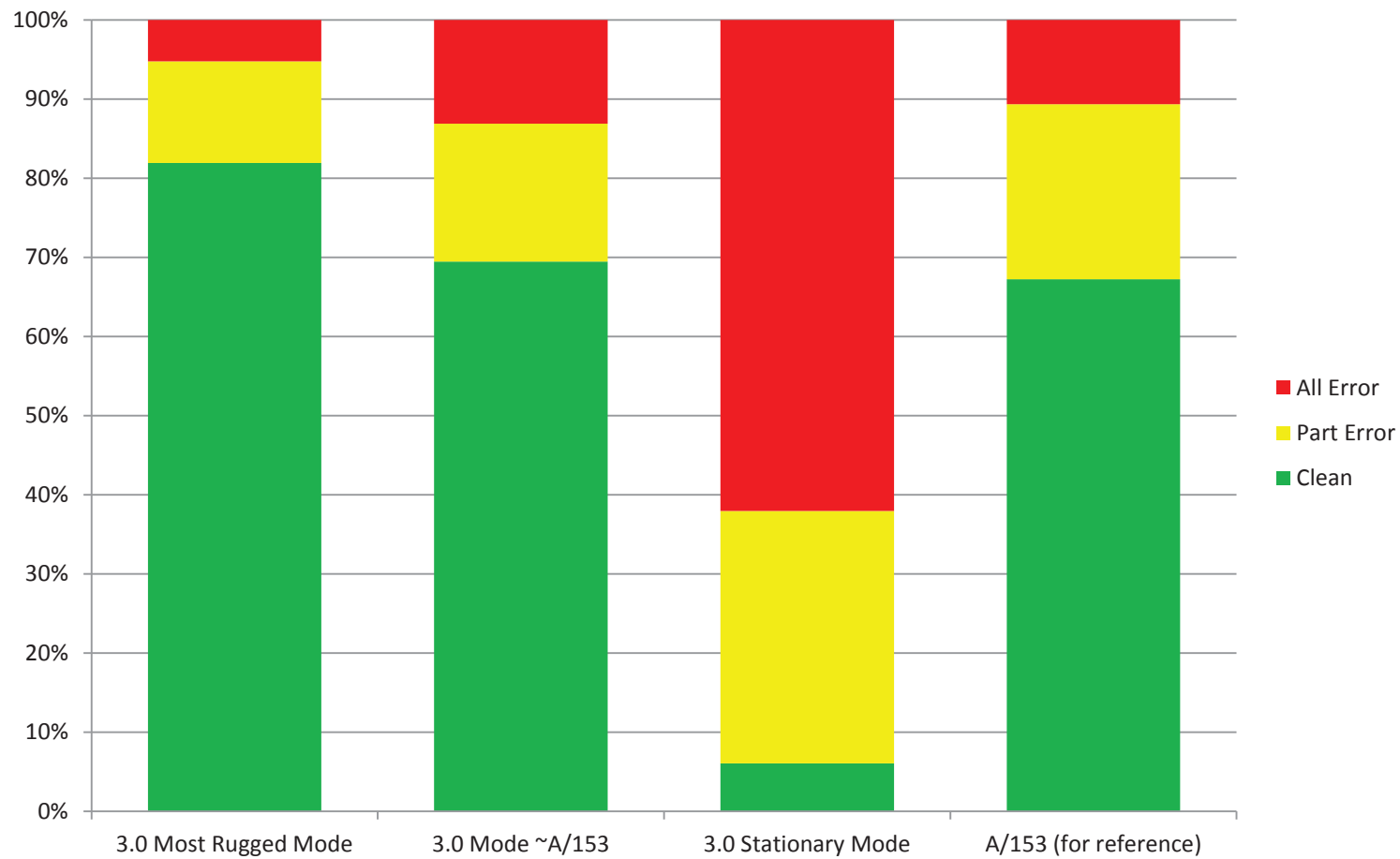
*Less data points for high-capacity mode because that receiver was neglected to be turned on during some of the routes

Mobile Reception Results for 3.3 dB SNR mode



Reception Results

ATSC 3.0 Field Test Results – Cleveland, June 2016



Discussion of Results

- Highly reliable in-vehicle mobile reception was achieved
 - Has positive implications for automotive industry: current and future (autonomous vehicles)
- Because challenging routes were chosen, results should not be considered as statistical over the entire service area
 - Our goal was to *challenge the system*
- For approximately equal modes (3.3 dB SNR), mobile 3.0 reception was equal to or better than that of A/153
- As anticipated, reception was poor using the stationary mode (SNR \sim 14 dB) for both ATSC 3.0 and ATSC 1.0 while vehicle was in motion

Field Test Conclusions

- FPGA implementations provided data capture of key performance values
 - Mobile Reception
 - Coverage
- Much lower thresholds than ATSC 1.0 are possible
 - Enables excellent Mobile Services
 - Enables deep indoor reception
- Same coverage area for the same threshold as ATSC 1.0 – for stationary reception
- Multiple, simultaneous transmission modes are realistic
 - Enables mobile services as well as high capacity data rates (HD & 4K)

Going Forward...

- We may return to Cleveland when we have full single-chip Silicon implementation of the 3.0 demodulator
- Industry Field Testing by NAB and CTA is being planned: Cleveland, and perhaps elsewhere as well

Appendix A:

More Technical Description of Testing

Based on Technical Paper provided at
the IEEE *Broadcast Technology*
Symposium, Hartford, CT; October 14,
2016

Three Simultaneous Transmission Modes

Three FPGA Receivers Used

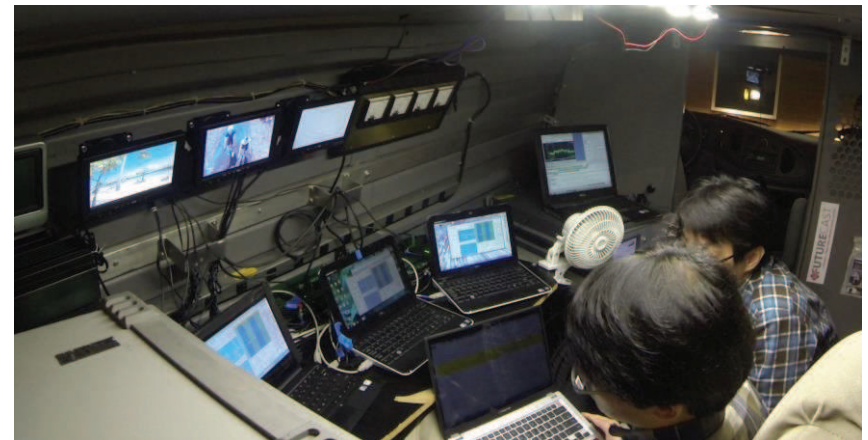
- PLP2 14.3 Mbps
@ 14 dB SNR
- PLP1 1.1 Mbps
@ 3.3 dB SNR*
- PLP0 0.5 Mbps
@ -1.3 dB SNR

For ATSC 1.0:

- 17.5 Mbps
@ 15 dB SNR
- 0.3 Mbps
@ 3.4 dB SNR* (M/H)

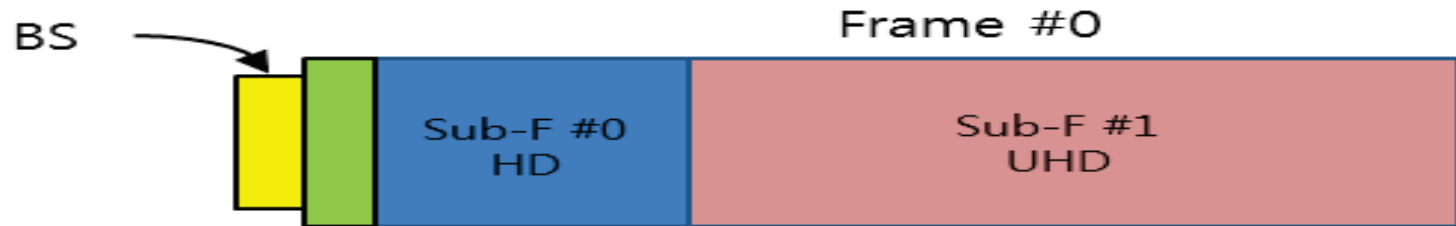
* For Comparison

Test Van has three receivers



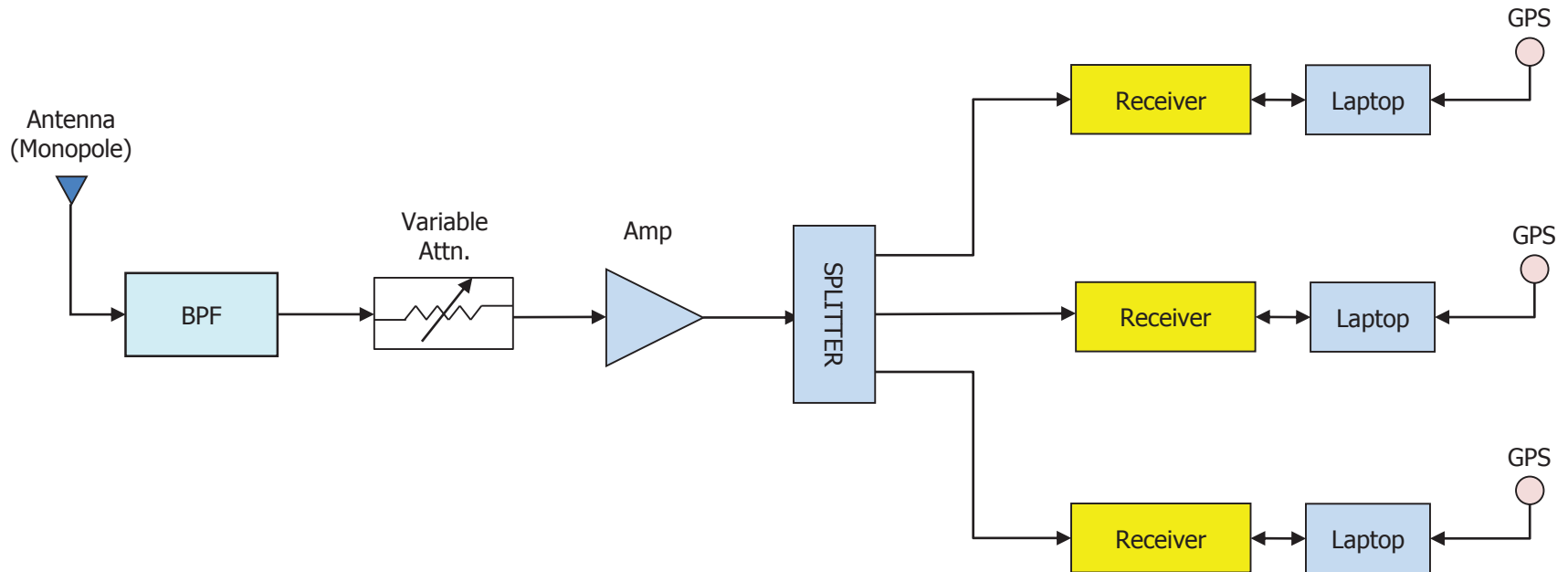
PLP = Physical Layer Pipe

ATSC 3.0 Modulation Parameters



	Preamble	PLP0	PLP1	PLP2
FFT	8K	8K	8K	32K
Inner Code (LDPC)	16K	16K	16K	64K
GI (μS)	148	111	111	111
Code Rate	3/15	5/15	5/15	8/15
QAM	4	4	16	256
Payload (Mbps)		0.5	1.1	14.3
TOV (dB)	-3.7	-1.3	3.3	13.9

Vehicle Test Setup



Appendix B:

Supporting Documents

Availability of Referenced ATSC Standards

See the ATSC website: www.atsc.org

ATSC 3.0, Next Generation Television, Standards

- A/321:2016, System Discovery and Signaling
- A/322:2016, Physical Layer Protocol

ATSC 1.0, Digital Television

- A/53, ATSC Digital Television Standard – Part 2: RF/Transmission System Characteristics
- A/153 ATSC-Mobile DTV Standard, Part 2 – RF/Transmission System Characteristics
- A/75:2001 – Developing DTV Field Test Plans (Recommended Practice)

News Release from Madison Tests – 1 of 4

FIELD TESTS OF FUTURECAST™ NEXT-GEN TV BROADCAST SYSTEM FIRST TO DEMONSTRATE ‘PHYSICAL LAYER’ CAPABILITIES OF 4K AND ROBUST MOBILE TRANSMISSION FOR ATSC 3.0

*Real-World Overnight Trials of FUTURECAST Hardware in Wisconsin
Shows Simultaneous Reception of 4K Ultra HD and Mobile TV Signals*

MADISON, Wis, Oct. 22, 2014 – While most TV viewers in Wisconsin’s capital city were fast asleep, the future of television broadcast technology was witnessed early this morning by a select group of broadcast industry professionals and expert viewers.

The next big step in terrestrial TV broadcasting is being demonstrated in Madison this week at Quincy Group’s WKOW-TV, which is conducting a second round of real-world broadcast field testing with the FUTURECAST™ Universal Terrestrial Broadcasting System.

Photos from the earlier Field Test in August can be [downloaded](http://bit.ly/FUTURECASTMadisonDemo) from this link: <http://bit.ly/FUTURECASTMadisonDemo>

FUTURECAST is a leading contributor to the optimal “physical layer” solution at the heart of the next-generation ATSC 3.0 broadcast standard, which is being standardized by the Advanced Television Systems Committee. FUTURECAST was co-developed by LG Electronics, its U.S. R&D subsidiary Zenith, and GatesAir as the foundation of next-generation terrestrial broadcasting in the United States and around the world.

Results from initial field tests completed in August – the first over-the-air broadcast trials of a complete ATSC 3.0 Physical Layer system – show how FUTURECAST can

News Release from Madison Tests – 2 of 4

deliver 4K Ultra HD content and two robust mobile TV streams in a single 6-Megahertz channel, while optimizing indoor reception and offering unparalleled spectrum efficiency.

The summer field test in Madison collected nearly 50,000 pieces of data from scores of reception sites including challenging reception areas inside buildings, in fast-moving vehicles and at locations ranging from downtown to 50 miles from the transmitter. This week's follow-up testing is evaluating performance of hardware and software enhancements and sharing the experience with key members of the broadcast and TV industries.

Today's three-hour FUTURECAST broadcasts on WKOW's Ch. 26 (PSIP 27), which began at 1 a.m., allowed outside observers (including representatives of the Wisconsin Broadcasters Association) to see what's possible with the new transmission system.

"It's exciting to play a role in the establishment of next-gen standards that will usher in the future of television," said Brady Dreasler, chief engineer for Quincy Group, parent company of WKOW-TV in Madison. "Based on what I've seen in these FUTURECAST tests, the new standard will enable exciting new business models for broadcasters and exciting new services for viewers."

The FUTURECAST Universal Terrestrial Broadcasting System is designed to provide the optimized combination of broadcasting capabilities for fixed, portable and mobile use. Flexible parameters allow broadcasters to mix diverse services – from fixed 4K reception to deep-indoor handheld reception to high-speed mobile reception – in a single RF channel with maximum efficiency.

"Initial testing results show the promise of the ATSC 3.0 standard to redefine television broadcasting. The FUTURECAST system is designed to fully meet broadcasters' requirements for the ATSC 3.0 physical layer and advances the goal of moving rapidly to next-gen broadcasting," said Dr. Skott Ahn, President and Chief Technology Officer, LG Electronics, co-developer of the FUTURECAST system.

News Release from Madison Tests – 3 of 4

Rich Redmond, Chief Product Officer for FUTURECAST co-developer Gates Air, said, “FUTURECAST, which we first demonstrated for the broadcast industry at April’s NAB Show, represents technology breakthroughs that will give broadcasters the transmission technology needed to support new business models, including mobile and LTE network offload, and compete effectively in the 21st Century.”

Expected to redefine TV broadcasting for decades to come, the overall next-generation broadcast television system will require higher capacity to deliver 4K Ultra-High-Definition services, robust reception on mobile devices and improved spectrum efficiency, according to the ATSC.

Key elements of the FUTURECAST system include:

- Data throughput increases of 30 percent and improved multipath performance (compared with the current DTV standard) for fixed and portable TV reception;
- Energy-saving features for consumer receivers and enhanced indoor TV signal penetration for mobile reception thanks to flexible system parameter choices;
- Advanced modes for delivery of very high data rates and very robust transmission capabilities;
- State-of-the-art error correction coding and signal constellations;
- Future Extension Frames to support evolution of future broadcast systems; and,
- Improved single frequency network service.

News Release from Madison Tests – 4 of 4

The increased payload capacity of the physical layer combined with HEVC encoding will allow broadcasters many more options when planning their broadcast service offering.

Designed for easy extension to various current and future transport formats, FUTURECAST optimizes efficiency for the most-used data formats (Internet Protocol, Transport Stream) via customized stream compression.

The system supports single-frequency networks and/or multiple transmitters, and its use of a single RF transmission's flexible physical layer profile assures optimum quality of service. The extensible new system is designed to support evolution to future broadcast systems even beyond ATSC 3.0.

FUTURECAST's superior RF approach addresses the co-channel and adjacent-channel interference challenges related to the anticipated UHF spectrum repacking.

The FUTURECAST Universal Terrestrial Broadcasting System is the latest collaboration among LG, Zenith and GatesAir, co-inventors of the transmission system behind the ATSC A/153 Mobile Digital TV Standard, adopted by the industry in 2009. Zenith invented the core transmission system at the heart of today's ATSC A/53 Digital Television Standard, approved by the Federal Communications Commission in 1996.

News Release from Earlier Cleveland Tests – 1 of 4

NEWS

FOR IMMEDIATE RELEASE

FIELD TESTS OF NEXT-GEN TV BROADCAST SYSTEM SHOW CAPABILITIES OF EMERGING ATSC 3.0 STANDARD

Cleveland Test Results Verify Improved Reception, Simultaneous Transmission of Mobile, Handheld and 4K Ultra HDTV Signals

CLEVELAND, July 10, 2015 – Television broadcasters will reach even more viewers with robust, digital over-the-air ATSC 3.0 signals, the improved broadcast transmission system under development now with key elements being field tested here this summer.

Under an experimental broadcast license from the FCC, Tribune Broadcasting’s WJW-TV is providing a TV transmitter, tower and 6-MHz channel for the ATSC 3.0-related field testing in Cleveland conducted since mid-May by LG Electronics, its Zenith R&D Lab, and GatesAir.

These real-world field tests represent an important milestone in the collaborative effort by LG, GatesAir and Zenith to develop core technologies behind the new ATSC 3.0 Standard. In fact, their innovations are expected to be used in the majority of the baseline Physical Layer transmission system, which is moving toward ATSC Candidate Standard status this summer.

This week in Cleveland, expert viewers visited a number of locations, witnessing how the more robust TV system will attract mobile viewers, connect viewers with Internet content, reach those in difficult reception locations, and delight owners of future 4K Ultra High-Definition TV sets with pristine 4K content delivered over-the-air using the new ATSC 3.0 standard.

The system being tested in Cleveland – dubbed “Futurecast” by proponents GatesAir, LG and Zenith – is a leading contributor to the effort to develop a next-generation ATSC 3.0 broadcast standard, which is being standardized by the Advanced Television Systems Committee.

Initial Results: Broader Coverage, More Viewers

Like similar field tests last fall in Madison, Wis., the Cleveland results are very encouraging. More than 75,000 pieces of additional data collected by engineers in the North Coast tests show how ATSC 3.0 will be able to deliver 4K Ultra HD content and two robust mobile TV streams in a single 6-Megahertz channel, while optimizing indoor reception and offering unparalleled spectrum efficiency.

News Release from Earlier Cleveland Tests – 2 of 4

Experts report that results in Cleveland are even more encouraging than the previous Wisconsin tests, with improved signal acquisition for mobile TV reception in fast-moving vehicles and at locations ranging from downtown's concrete canyons to suburban and rural areas 50 miles from the transmitter.

"We're pleased to play an integral role in the future of TV broadcast technology, putting an unused transmitter and vacant channel to use so that the proposed transmission system could be tested throughout the day and night. These initial field test results show that ATSC 3.0 technologies are real and can deliver real benefits to broadcasters and viewers alike," said John Cifani, chief engineer of WJW-TV, the local Fox affiliate.

The Futurecast physical layer technologies are designed to provide the optimized combination of broadcasting capabilities for fixed, portable and mobile use. Flexible parameters allow broadcasters to mix diverse services – from fixed 4K reception to deep-indoor handheld reception to high-speed mobile reception – in a single RF channel with maximum efficiency.

Improved Reception, Flexibility for New Business Models

"Our technology is designed to fully meet broadcaster requirements for ATSC 3.0 and advance the goal of moving rapidly to next-generation broadcasting. Whether watching from deep inside a building or along the Lake Erie lakefront, field test results show that our ATSC 3.0-enabling technology performs exactly as expected," said Dr. Skott Ahn, President and Chief Technology Officer, LG Electronics.

"This means that broadcasters can look forward with confidence to reaching even more viewers with traditional television, with new Internet-based content, and with new money-making interactive services and advertising capabilities," he said.

News Release from Earlier Cleveland Tests – 3 of 4

Key benefits of the LG/GatesAir/Zenith ATSC 3.0 technologies being field tested in Cleveland include:

- Data throughput increases of 30 percent and improved multipath performance (compared with the current DTV standard) for fixed and portable TV reception;
- Enhanced indoor TV signal penetration for mobile reception thanks to flexible system parameter choices;
- Advanced modes for delivery of very high data rates and very robust transmission capabilities;
- State-of-the-art error correction coding and signal constellations;
- Future Extension Frames to support evolution of future broadcast systems; and,
- Improved single frequency network service.

Advanced Emergency Alerting with ATSC 3.0

Rich Redmond, Chief Product Officer for Gates Air, said, “Not only will reception be improved, but the advanced IP-based distribution and mobile broadcasting capabilities of ATSC 3.0 will shine through in times of emergency. Our collaborative innovations will support industry-wide efforts to evolve over-the-air business models, support next-generation warning systems and extend the reach of digital TV across greater populations.” Redmond adds that this includes leveraging AWARN (the Advanced Warning and Response Network) to deliver broadcast emergency announcements to TV sets and mobile devices containing rich media, maps, graphics, video, text, and audio.”

In addition to participating in field testing of ATSC 3.0 enabling technologies, expert viewers here today witnessed advanced emergency alerting capabilities thanks to a demonstration hosted by local CBS affiliate WOIO-TV, a Raycom Media station and member of the Pearl TV broadcast technology partnership.

AWARN will capitalize on the robust transmission and improved mobile and fixed reception promised by ATSC 3.0, according to WOIO-TV General Manager Dominic Mancuso.

“Local broadcasters are vital links to our viewers here in Cleveland and across the country. Our viewers know that they can trust us to have the latest information in times of public safety emergencies. With ATSC 3.0 and AWARN, the public won’t be dependent on Internet or local phone service,” he said.

News Release from Earlier Cleveland Tests – 4 of 4

Redefining Broadcasting's Future

Expected to redefine TV broadcasting for decades to come, the next-generation broadcast television standard will require higher capacity to deliver 4K Ultra-High-Definition services, robust reception on mobile devices and improved spectrum efficiency. The increased payload capacity of the physical layer combined with HEVC encoding will allow broadcasters many more options when planning their broadcast service offerings.

Designed for easy extension to various current and future transport formats, the LG/GatesAir/Zenith solutions optimize efficiency for the most-used data formats (Internet Protocol, Transport Stream) via customized stream compression.

The system supports single-frequency networks and/or multiple transmitters, and its use of a single RF transmission's flexible physical layer profile assures optimum quality of service. The system is designed to support evolution to future broadcast systems even beyond ATSC 3.0.

Equally significant, the superior RF approach of the proven Futurecast system addresses the co-channel and adjacent-channel interference challenges related to the anticipated UHF spectrum repacking.

Development of ATSC 3.0 technologies represents the latest collaboration among LG, Zenith and GatesAir, co-inventors of the transmission system behind the ATSC A/153 Mobile Digital TV Standard, adopted by the industry in 2009. Zenith invented the core transmission system at the heart of today's ATSC A/53 Digital Television Standard, approved by the Federal Communications Commission in 1996.